A DUAL MODE DISPLAY WITH A BACKLIGHT FILTER FOR AN UNACTIVATED LIGHT EMITTING DIODE (LED)

UNITED STATES GOVERNMENT RIGHTS

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BACKGROUND OF THE INVENTION

Field of the Invention (Technical Field):

The invention relates to displays and more particularly to dual mode transmissive display backlighting of color displays for use in a night mode such as in conjunction with Night Vision Goggles (NVG).

Background Art:

A design of a Liquid Crystal Display (LCD) was needed with a backlight with two different modes of operation with different colors for each mode. An additional requirement was that one of the modes, the night mode, be compatible with Night Vision Imaging System (NVIS) requirements of MIL-L-85762A. This mode, NVIS mode, was also required to have a particular color as defined in MIL-L-85762A as NVIS Green A. The other mode of operation, day mode, needed to provide full daylight readability of the display in an avionic high ambient illumination condition, and was required to be white. The backlight illumination source was selected to be white LEDs for both modes of operation. The particular problem, which was encountered with the initial design, was associated with the phosphorescence of the day mode LEDs when they were illuminated with radiant energy from the NVIS filtered night mode LEDs. The day mode LEDs absorbed NVIS compatible illumination and re-radiated non-compliant energy. This phosphorescence caused the display to fail the NVIS requirements of MIL-L-85762A.

A typical dual mode backlight would provide an NVIS filter that acts only in the NVIS mode lighting source, which would not prevent the phosphorescence of the day mode lighting source from creating NVIS problems through phosphorescence. Other day mode lighting sources (incandescent lamps, fluorescent lamps, etc.) do not typically exhibit phosphorescence in the NVIS region of interest (i.e., absorption in visible spectrum, 380-780nm, and re-emission in the NVIS spectrum, 570-930nm). Placing a conventional NVIS filter over the day mode lighting source would severely limit the efficiency of the day mode lighting system, which would require the use of more LEDs and more power to achieve day mode requirements of legibility in high ambient illumination conditions.

There are patents for dual-mode backlights/displays, which are NVIS compatible. However, the previous designs use different illumination sources, and do not require the optical filtering techniques required for the present invention. The introduction of white LEDs caused the issue to arise. LEDs were selected for this particular design for several reasons. They have improved reliability relative to other types of lighting sources (i.e., incandescent lamps, fluorescent lamps), and they perform extremely well over a very wide operating temperature which is advantageous for demanding environmental conditions as are typically encountered with avionic or automotive display products. LEDs are also very easy to drive electrically and to dim as is required for backlights in avionic applications. Typically, if a material phosphoresces and causes problems with NVIS radiance, the material is removed from the design or it is placed behind the NVIS filter. Due to the use of the white LEDs for the day mode backlight design, removal is not possible, and filtering with a typical NVIS filter would significantly inhibit meeting the day mode requirements, thereby eliminating one of the natural advantages of a dual mode backlighting system.

There are several prior art devices that disclose dual mode backlighting systems. These include U.S. Patent No. 5,986,730, for an LCD that is both transmissive and reflective and U.S. Patents Nos. 6,285,425 and 6,285,426, which involve using a reflector to allow a display to be illuminated from ambient light.

Some of the prior art devices that use an NVIS filter for filtering the NVIS light source include U.S. Patent No. 5,982,090, which discloses a special kind of flat fluorescent lamp used in LCD backlighting and U.S. Patent No. 6,039,451, which teaches the use of a transflector that is used to enhance day mode luminance. U. S. Patent No. 6,419,372 is a dual mode LED backlighting system that uses a light guide to distribute the two different LED lighting systems. This system includes NVIS filtering that is only applicable to the night mode LEDs and does not address the issue of phosphorescence, which will result from the NVIS illumination radiating onto the day mode LEDs.

None of the prior art devices teach or imply the use of a filter placed over the inactive or "day mode" light source as presently described in the present application.

SUMMARY OF THE INVENTION (DISCLOSURE OF THE INVENTION)

In accordance with the present invention, there is provided a dual mode or multimode backlight for a display. The preferred backlight enables two different colors of backlighting for a transmissive monochrome display, using a highly efficient filter to enable daytime viewing with one system while still meeting the stringent NVIS requirements with the other lighting system. This invention enables the use of white or different colored LEDs in an NVIS compatible mode of operation when they are not activated, which is necessary for display backlighting systems and especially for cockpit illumination systems.

A primary object of the present invention is to enable the use of white LEDs for an NVIS compatible display with a dual mode backlighting system.

A primary advantage of the present invention is that it achieves NVIS compliance with one array of white LEDs, while maintaining the ability to meet demanding daytime requirements with another array of white LEDs. This permits the use of white LEDs for this type of application over other lighting sources. LEDs

have several advantages including longer life, instant on at cold temperatures, very little change in output illumination over a wide temperature range, simple drive electronics, very wide dimming range, simplified assembly construction, and environmentally friendly manufacturing.

Other objects, advantages and novel features, and further scope of applicability of the present invention will be set forth in part in the detailed description to follow, taken in conjunction with the accompanying drawings, and in part will become apparent to those skilled in the art upon examination of the following, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and attained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated into and form a part of the specification, illustrate several embodiments of the present invention and, together with the description, serve to explain the principles of the invention. The drawings are only for the purpose of illustrating a preferred embodiment of the invention and are not to be construed as limiting the invention. In the drawings:

Fig. 1 is an exploded view of the preferred dual mode backlight.

Fig. 2 is a cut out view of the embodiment of Fig. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS (BEST MODES FOR CARRYING OUT THE INVENTION)

Fig. 1 shows an exploded view of the preferred backlight and Fig. 2 shows a cut out view of the preferred backlight containing a more detailed view of the particular features of the present invention. Backlight **10** consists of a housing or

light cavity **12** for directing light **20** to the display source **14** such as an LCD. As is well known in the art, display source **14**, such as a liquid crystal display, is illuminated by the backlight **10**. Backlight **10** is preferably fabricated from a material that does not transmit light, such as aluminum or plastic and is preferably coated on the inside with reflective material **16**. Reflective material **16** can either be a diffusely reflective material or a specularly reflective material. Backlight **10** is preferably opened on a first end **18** to direct light **20** to a display source **14** such as a LCD.

LEDs **22** and **24** are installed inside the light cavity **12**. In the preferred embodiment, light cavity **12** contains three distinct sub cavities. A night mode cavity **44** is formed by NVIS filter **34** and night mode LEDs **24**. A day mode cavity **46** is formed by second filter or hot mirror **36** and day mode LEDs **22**. A common or primary cavity **48** is formed by a rear of the LCD diffuser **50,** cavity walls **52** and the front sides of NVIS filter **34** and hot mirror **36**. The preferred light cavity **12** is constructed to minimize the exposed area of the NVIS filter **34**, thus making the backlight **10** more efficient. This construction comprises small apertures **42,** which allow NVIS filtered light to enter into primary cavity **48** for limiting the exposure of the NVIS filter **34**. Apertures **42** can be sized individually to balance or to provide improved uniformity of the backlight illumination. Typically NVIS filters absorb large amounts of light. Therefore, if a face of a NVIS filter is fully exposed to one or more LEDs, and is not limited by designs such as the small apertures **42** as used in the present invention, the amount of light output from the backlight for either the NVIS or day mode LEDs would be significantly reduced. LEDs **22** and **24** may be mounted on a printed wiring board (PWB) **26** or other mounting structure well known in the art. PWB **26** provides interconnect to the LEDs **22** and **24**, thereby simplifying the construction of backlight **10**. PWB **26** can also serve as the rear surface **40** of the backlight assembly **10,** which helps to contain the light generated by the LEDs **22** and **24** and direct the light to the LCD diffuser **50** and subsequently through LCD **14**. LCD **14** is located adjacent to the front side of LCD diffuser **50,** as shown. The PWB **26** can also serve as a heat sink for the LEDs **22** and **24** to remove heat. Filter housing **28** is fitted over the LEDs **22** and **24** in such a way as to

separate the day mode LEDs **22** and night mode LEDs **24** and provide mounting surfaces for a day filter **36** and a night filter **34**. Filter housing **28** is preferably constructed from a material that does not transmit light such as metal or plastic. Filter housing **28** with filters **36** and **34** installed separates the day mode **22** and night mode LEDs **24** preventing unfiltered light from being exchanged between them. A filter housing would not be necessary if the filters themselves were designed in such a way as to accomplish the same thing. For example, if the filters were cylindrical in shape and covered the LEDs, the filter housing would not be required. A conventional NVIS filter **34** is installed on the filter housing **28** over the night mode LEDs **24**. NVIS filter **34** acts as a filter for the night mode LEDs **24**. NVIS filter **34** removes red and near infrared energy from the emitted light and filters for the required emitted color. This filter **34** enables the light passing through the LCD **14** to meet NVIS requirements for radiance and color. A second filter **36**, such as a hot mirror, is installed over the day mode LEDs **22**. This second filter **36**, is selected to filter the phosphorescent light **23** emitted from the day mode LEDs **22** thereby removing sufficient infrared content to enable the system to meet NVIS radiance requirements. In the preferred embodiment a hot mirror is used as the second filter **36**.

Although a hot mirror is used in the preferred embodiment, this disclosure is meant to cover all other types of filters such as narrow band reflective notch or narrow band absorptive filters, that are well known in the art. The critical characteristics of second filter **36** are that it must have very high transmission (>80%) in the visible spectrum (approximately 380-650nm), and have sufficient attenuation (~90%) in the spectral region in which the day mode light source phosphoresces, which is within the NVIS goggle region of sensitivity (570-930nm). This attenuation can be accomplished through either reflection or absorption but is most effectively accomplished through reflection. The white LEDs have a broad band phosphorescence; consequently, the selected filter needs to attenuate near-infrared energy from approximately 750nm to at least 930nm to provide NVIS compatible lighting for night mode. Depending upon the magnitude of phosphorescence and the required level of NVIS performance as defined in MIL-L-

85762A, the attenuation can begin at wavelengths further out into the near-infrared region (e.g., 800nm to 930nm). The shift in attenuation towards higher wavelengths is advantageous because this minimizes the effect of the filter on the day mode lighting, in particular the color of the day mode lighting is improved by shifting the attenuation characteristic further into the infrared region. If the filter's characteristic shifts as a function of angle as is the case with typical thin film optical coatings due to the difference in optical path length, the attenuation or reflective characteristic of the filter needs to be extended beyond the NVIS spectral region of 930nm. This is to account for the performance of the filter with light, which is passing through the filter at higher angles of incidence. Consequently, a filter that has sufficient attenuation out to at least 1100nm is desired for a broad band phosphorescing material. Other materials phosphoresce over a narrow spectral region, which would only require a narrow band filter that attenuated the specific wavelengths at which the phosphorescence occurs. The filter and housing assembly **38** separates the LEDs **22** and **24** in such a way as to prevent exchange of unfiltered light.

With all dual mode backlights using LEDs, light from the night mode LEDs **24** floods the primary backlight cavity **12**. Some of the light **21** impinges on the day mode LEDs **22**. The energy excites the LEDs phosphor and caused the day mode LEDs **22** to phosphoresce **23**. The phosphorescent light has sufficient energy content in the infrared region to cause the system to cause the day mode LEDs **22** to "light up" and degrade the night mode backlight system and thus, fail NVIS radiance. The hot mirror **36** corrects this problem by filtering the phosphorescent light emitted **23** from the day mode LEDs **22**, thereby removing sufficient infrared content to enable the system to meet NVIS radiance requirements. Hot mirror **36** has filter characteristics that attenuate the infrared energy emitted from the day mode LEDs **22**. It is designed to allow the maximum amount of day mode light to pass through. When the day mode LEDs **22** are operational, hot mirror **36** attenuates a minimal amount of visible light thereby maximizing day mode luminance.

During day mode operation, backlight **10** is turned on by activating the electrical drive of the day mode LEDs **22** and disabling the electrical drive of the

night mode LEDs **24**. The illumination from the day mode LEDs **22** passes through hot mirror **36** and floods the primary lighting cavity **48** providing rear illumination onto the backlight diffuser **50**. A small portion of visible spectrum and a large portion of the near-infrared spectrum of the LED illumination is attenuated by hot mirror **36**. When the illumination is incident upon the diffuser **50**, some of the illumination passes through it and subsequently through LCD **14** to the display user, the remainder of the illumination scatters backward from the diffuser **50** or off of the reflective **16** sidewalls of the backlight cavity **12**. This reflected illumination is conserved through multiple reflections within backlight cavity **12**, eventually passing through diffuser **50** to the user or it is lost to absorption in the exposed areas of the NVIS filter **34** covering the NVIS LEDs **24**.

During night mode of operation, backlight **10** is turned on by activating the electrical drive of night mode LEDs **24** and disabling the electrical drive of the day mode LEDs **22**. The illumination from night mode LEDs **24** passes through NVIS filter **34** and floods primary lighting cavity **48** providing rear illumination onto the backlight diffuser **50**. NVIS filter **34** attenuates the red and near-infrared portion of the spectrum to provide a NVIS compliant color of light, such as NVIS green A, and to provide NVIS radiant compliant illumination. When the illumination is incident upon diffuser **50**, some of the illumination passes through it and subsequently through LCD **14** to the display user. The remainder of the illumination scatters backward **21** from diffuser **50** or is reflected off of the sidewalls of backlight cavity **12**. Some of the illumination within backlight cavity **12** passes through hot mirror **36** and irradiates the day mode LEDs **22**. Day mode LEDs **22** phosphoresce converting this NVIS compliant illumination to higher wavelengths which are not compliant to the NVIS requirements. The phosphorescent illumination then passes through hot mirror **36** where the non-compliant near-infrared energy is attenuated to render it NVIS compliant. Some of this filtered phosphorescent illumination passes through diffuser **50** and through LCD **14** to the display user, while the remainder is cycled in a similar manner through multiple reflections or is lost to absorption in the exposed areas of NVIS filter **34**.

Although the discussion above describes a dual use backlight, the present invention can be used for a multimode backlight. For instance more than one night mode can be provided in the backlight with different colors representing different conditions. Additionally, more than one day mode can be provided in the backlight with different colors of LEDs for different conditions.

The present invention could be used in an alternative embodiment by using color LEDs for night mode operation. The hot mirror could also be placed over both sets of LEDs (not shown). This variation would be limited in that the color options would be limited by the color of the LED's.

The invention would have commercial application for electronics with displays where the user uses night vision imaging systems. This is becoming increasingly prevalent in law enforcement. Applications for the present invention can include but not limited to avionics displays, ground vehicle instruments or displays and hand-held instruments or displays.

Although the invention has been described in detail with particular reference to these preferred embodiments, other embodiments can achieve the same results. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents. The entire disclosures of all references, applications, patents, and publications cited above, are hereby incorporated by reference.